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Henry L. Taylor, Captain, USAF
James C. Smith, Ph.D.
C. Ann Hatfield, B.S.

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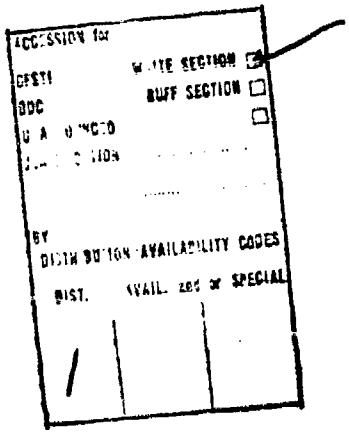
6571st Aeromedical Research Laboratory
Aerospace Medical Division
Air Force Systems Command
Holloman Air Force Base, New Mexico

The animals used in this study were handled in accordance with the "Guide for Laboratory Animal Facilities and Care" as promulgated by the National Academy of Sciences - National Research Council.



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FOREWORD

This report is based on a study conducted jointly by the 6571st Aeromedical Research Laboratory and the Florida State University, Tallahassee, Florida. The work was completed in July 1967 and was supported by United States Air Force contract number F29600-67-C-0012 under Project 6893, and by United States Atomic Energy Commission contracts AT-(40-1)-2903 and AT-(40-1)-2690 with the Florida State University.

This technical report has been reviewed and approved.

H.H. REYNOLDS, Lt Colonel, USAF
Deputy Commander

ABSTRACT

Immediate detection of X-rays (.63r/sec.) in four rhesus monkeys was demonstrated through the use of the conditioned suppression technique. Detection was evident in three monkeys after 20 trials in which X-rays and unavoidable shock were paired, and after 5 trials of pairing X-rays and shock for one monkey. Dose rate was decreased to .03r/sec. and all subjects showed a high level of response suppression in the presence of X-rays, but no suppression of response was evident during control trials.

I

INTRODUCTION

Ionizing irradiation has been used both as a motivating and as a discriminative stimulus. Conditioned taste aversion, which demonstrates the motivating properties of irradiation, has been shown in several species including mice, rats, cats (1), and rhesus monkeys (2). Investigations involving arousal from sleep (3) and suppression of behavior (4) have shown the discriminative properties of radiation.

Using a conditioned suppression technique, Morris (5), demonstrated immediate detection of X-rays in rats. He found that behavior maintained by a positive reinforcement schedule was suppressed in the presence of X-rays (.5r/sec.), when the irradiation was terminated by an unavoidable electric shock. Morris also reported a high level of suppression at dose rates as low as .04r/sec. Smith, Hendricks, Morris, and Powell (6) have also reported immediate behavioral detection of X-rays in the pigeon.

There have been no studies, however, using X-rays as a discriminative stimulus with primates. The purpose of the present research was to utilize the conditioned suppression technique to investigate immediate detection of X-rays by the rhesus monkey.

II

METHOD

A. SUBJECTS

The subjects were four male rhesus monkeys (Macaca mulatta) whose ages were estimated to be between 36 and 48 months, and whose weights at the start of the experiment were between 4.1 and 4.9 kgs. The monkeys were housed in individual home cages where water was continuously available, and they

were maintained at approximately 90 percent of their normal body weight. Prior to this study, two of the subjects were used in a delayed match-to-sample study.

B. APPARATUS

A schematic of the apparatus is provided in Figure 1. A standard Foringer primate chair mounted on slides in a booth was used to restrain the subject during experimentation. A standard Foringer lever was used as the response manipulandum, and a Foringer pellet dispenser was used to deliver reinforcement. A red light, which served as a discriminative stimulus for reinforcement, was mounted on a panel attached to the primate chair. Three white house lights provided illumination for the operation of a closed circuit television camera located beneath the chair. A pentaprism and a mirror were used to focus the camera on the monkey's head. The booth was housed in a sound attenuating acoustical chamber which was positioned adjacent to the X-ray tube. Sound pressure level measurements and sonograms of sounds in the booth indicated that X-ray machine noises were completely masked by an 85 decibel masking noise which was presented via a speaker mounted on the ceiling of the booth. Circulation inside the booth was maintained by a blower fan which drew air through a series of baffles.

The X-rays were produced by a 300 kv. General Electric Maxitron X-ray machine which was operated at 250 kvp, 20 ma., with 3.0 mm. Al filtration. Dosimetry was accomplished by placing a Victoreen thimble chamber in the position of the center of the subject's head, and a target distance of 61 cm. (24 inches) yielded a dose rate of .63r/sec. The outside of the acoustical chamber and one side and the top of the primate chair were lined with lead which shielded the subject's body from X-rays (see Figure 1). A circular port, 20.3 cm. (8 inches) in diameter, was cut in the lead shielding on the side of the chamber. The tube was operated in the horizontal position and was aligned with the port, thus permitting head-only exposure to the X-rays. A Phillips dose rate recording meter was used to monitor the X-ray exposures.

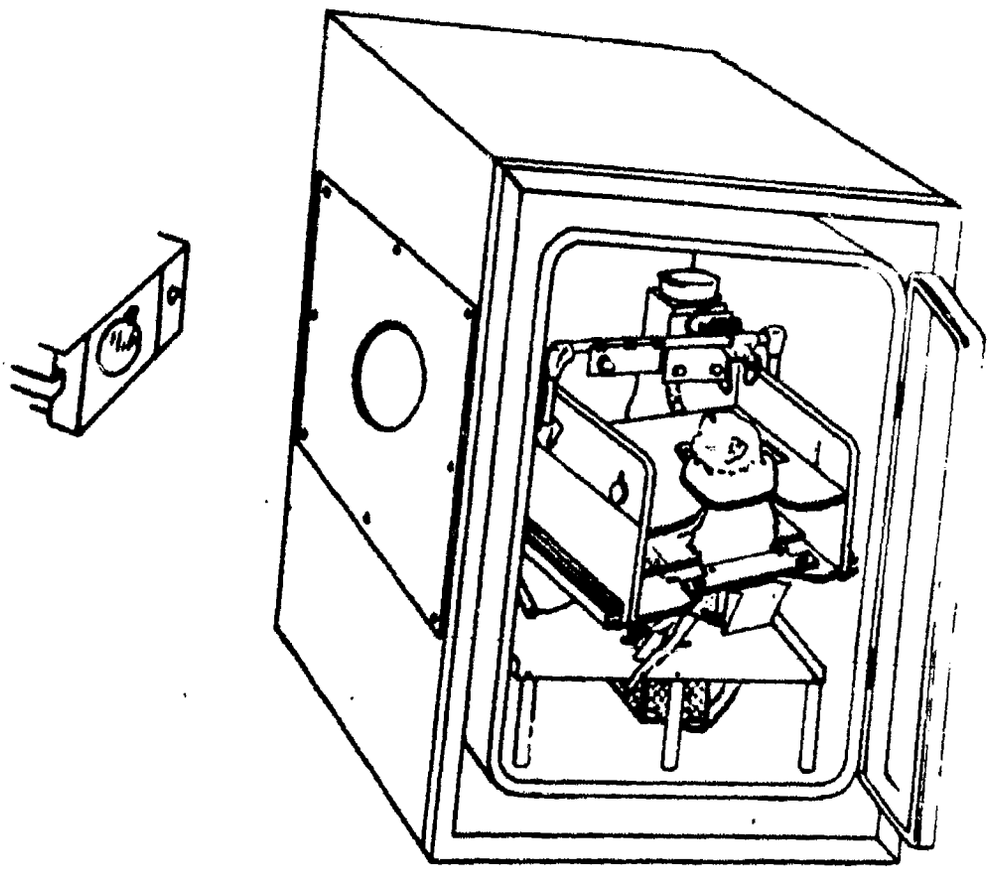

Figure 1. Schematic of the apparatus.

Programming of the behavioral schedule was accomplished by standard relay switching and timing circuits located in the X-ray control room. Response, reinforcement and stimulus events were recorded on digital counters, a cumulative recorder, and a strip chart recorder. Electric shock was generated by a Grason-Stadler shock generator and was presented to the subject across the chair seat and a brass foot plate (7).

C. PROCEDURE

Prior to each experimental session the subjects were led, using a collar and chain procedure (8), from the home cage to the experimental booth and seated in the restraint chair. Lever pressing behavior was initially maintained by continuous reinforcement and subsequently by low variable ratio (VR) schedules which were slowly extended to a VR:200. On a VR:200 schedule the ratio of responses to each reinforcement is, on the average, 200; but the ratio varies from reinforcement to reinforcement. When responding on the VR:200 schedule was stable, the subjects were shifted to a variable interval (VI) 90-second schedule; that is, response contingent reinforcement was available on the average of once every 90 second. The reinforcers used throughout the study were 0.7 gm D&G[1] whole diet monkey pellets. All experimental sessions were approximately 1 hour in duration.

Following several sessions on the VI 90-second schedule, conditioned suppression training using X-rays as a discriminative stimulus was initiated. During each 1-hour session approximately 10 suppression trials, 5 control trials, and 5 baseline trials were given during the inter-reinforcement intervals. A suppression trial consisted of presenting X-rays (.63r/sec.) to the head of the subject during a 15-second interval and terminating the X-ray presentation with an unavoidable electric shock. To determine that suppression was not related to auditory stimuli associated with X-ray presentation, control data were collected. The control trials consisted of operating

[1] Dietrich and Gambrill, Inc., Foringer and Company, Inc. 535-A Southlawn Lane, Rockville, Maryland 20850

the X-ray machine for a 15-second period with the tube shielded and directed away from the acoustical chamber. Baseline trials consisted of recording the responses which occurred for two consecutive 15-second periods of time. The baseline trials were used to demonstrate that the suppression behavior was not under the control of artifacts from the lighting or white noise systems during the operation of programming timers and relays. In addition, baseline trials permitted the assessment of baseline stability of the lever pressing response. The two types of control trials were never terminated by shock.

A suppression ratio was used to quantify the degree of suppression (9). The ratio was computed as follows: $\frac{T_1 - T_2}{T_1}$ where T_1 was the number of responses during the 15-second period preceding the X-ray or control exposure trial, and T_2 was the number of responses during the 15-second X-ray exposure or control period. Complete suppression results in a ratio of 1.00; and if responding is equal during T_1 and T_2, the ratio is 0.00. A greater number of responses during T_2 than during T_1 results in a negative suppression ratio.

When the mean suppression ratio for X-ray trials during one experimental session reached .80, the dose rate was reduced in discrete steps and additional data were collected at dose rates of .13, .07, and .03r/sec. Dose rate was decreased by increasing the distance from the tube to the subject and by reducing the X-ray tube current from 20 ma. to 5 ma.

III

RESULTS

The rate of response maintained by the VI 90-second schedule of reinforcement was high and steady for all subjects. The mean response rate for the last five experimental sessions prior to initiation of conditioned suppression training ranged from 118 to 192 responses per minute for the four subjects.

Suppression in the presence of X-rays (.63r/sec.) was clearly evident early during suppression training. Table I presents a summary of the data obtained during acquisition of suppression. The median suppression ratios for blocks of five consecutive trials are shown for X-ray, baseline, and control trials. A Kruskal-Wallis analysis of variance by ranks was run for each block of five trials for each subject testing the difference between X-ray, baseline, and control trials. Subjects M389, M283, and M391 reached the .01 level of significance after 20 trials, and M390 reached this significance level after only 5 trials. It is clear from the data in Table I that no difference exists between the two types of control trials for subjects M389, M283, and M391, and that the obtained difference was due to differential suppression behavior during X-ray trials and baseline and control trials. Even for subject M390, the difference between the X-ray and control trials was significant beyond the .05 level of confidence as tested by a Mann-Whitney test.

After three sessions, M391, M390, and M389 reached the criterion for reducing the X-ray dose rate; that is, a mean suppression ratio of .80 for X-ray trials during one experimental session. The number of suppression trials required to meet the criterion was 26, 23, and 22 trials for subjects M391, M389, and M390 respectively. The cumulative radiation dose during the suppression training was 260r, 230r and 220r respectively for these subjects. M283, however, required 11 sessions and 109 suppression trials to reach the criterion, and the cumulative radiation dose prior to the reduction of the dose rate was 1090r. The mean suppression ratio for M283 after the third suppression training session was .63; but during the fourth and several succeeding sessions, the subject escaped the bindings which held the foot in close contact with the foot electrode. The termination of X-ray trials with unavoidable shock was inconsistent during these sessions; and consequently, stimulus control was lost. Control was regained during the eighth session, and M283 reached the criterion for reducing the radiation dose rate on the 11th session.

Table I. Median Suppression Ratios in Blocks of Five Trials.

Subject	Block	Suppression Ratio			X^2	Level of significance
		X-ray	Baseline	Control		
M391	1	.29	.14	.12	2.22	.50
	2	.60	.09	-.05	2.66	.50
	3	.60	-.03	.26	6.60	.05
	4	1.00	-.07	.02	11.18	.01
M283	1	.08	.12	.11	1.14	.70
	2	.26	-.05	.19	1.86	.50
	3	.56	.59	.05	1.82	.50
	4	.81	06	-.11	10.22	.01
M389	1	.45	.00	.03	4.46	.20
	2	.12	.00	.03	2.05	.50
	3	.45	.12	.03	4.16	.20
	4	.78	-.06	.00	11.58	.01
M390	1	.74	.08	.33	10.14	.01

Responding during T_1 and T_2 for baseline, X-ray and control trials is illustrated in Figure 2. The strip chart recordings were obtained from subject M391 after the dose rate was reduced to .13r/sec. The recordings, however, are representative of all subjects at the lower dose rates (.13r/sec. and below). There is no evidence of response suppression for the baseline and control trials, but responding is clearly suppressed during the X-ray trials (a suppression ratio of approximately .90). Since onset of X-rays was programmed manually by the experimenter rather than by relay switching, precise measurement of latency of suppression was impossible from the strip chart recordings; but suppression was typically evident within 1 to 1-1/2 seconds after onset of X-rays. The differential suppression behavior, during X-ray trials when compared to control and baseline trials, is regarded as unequivocal evidence that suppression is a consequence of X-ray detection and not due to auditory stimuli resulting from X-ray tube operation or artifacts from the masking noise or lighting systems.

The subjects were observed, via closed circuit TV, throughout each experimental session. Head movement appeared more specific for all subjects during X-ray trials than the random head movement observed during baseline and control trials. For example, M283 typically turned away from the direction of the X-ray beam during exposure, and M391 sometimes turned toward and sometimes turned away from the beam.

Response suppression during X-ray trials was maintained for all subjects when the dose rate was decreased in discrete steps from .63r/sec. to .03r/sec. Suppression was not evident during baseline and control trials for any subject throughout the study. The mean suppression ratios for each subject for the last five X-ray, baseline, and control trials at the four radiation dose rates are shown in Table II. The lowest mean ratio obtained during X-ray trials was .65 and 13 of 16 mean ratios are .80 or higher. The mean suppression ratios for the baseline and control trials, however, vary in a non-systematic manner around 0 with a range from -.36 to .27.

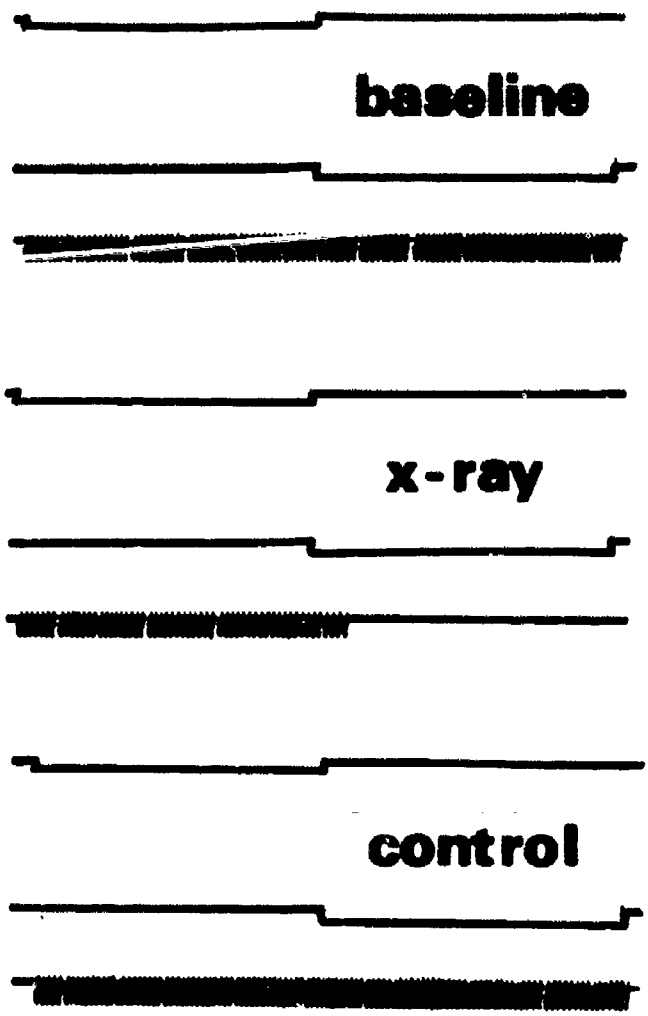

Figure 2. Representative strip chart recordings of T_1 and T_2 for a baseline, X-ray and control trial from M391, dose rate .13r/sec. Pen deflections are: top line, T_1; middle line, T_2; bottom line, responses. Behavior proceeds from left to right.

Table II. Mean Suppression Ratios for the Last Five Trials at Each Radiation Dose Rate.

Subject	Dose Rate r/sec	Suppression Ratio X-ray	Baseline	Control
M391	.63	.89	.27	.25
	.13	.90	.03	-.03
	.07	.70	-.36	.18
	.03	.81	-.06	.10
M283	.63	.89	-.06	-.21
	.13	.90	.07	-.06
	.07	.80	.01	.05
	.03	.83	.15	.05
M389	.63	.82	.21	.01
	.13	.80	.01	.01
	.07	.81	.00	-.01
	.03	.71	-.09	.12
M390	.63	.87	.08	.20
	.13	.80*	.08	.20
	.07	.65	-.13	.07
	.03	.84	.14	.06

*Based on two trials

IV

DISCUSSION

The present study demonstrates that the conditioned suppression technique is an effective procedure for investigating the use of X-rays as a discriminative stimulus in primates. Immediate detection of X-rays was clearly demonstrated in each of the four monkeys. There was no evidence of loss of stimulus control as the dose rate was decreased from .63r/sec. to .03r/sec. These results are comparable to data which were obtained by Morris (5). He used the white rat as the experimental subject; and he reported that as radiation dose rate was decreased from .5r/sec. to .04r/sec., suppression ratios remain essentially unchanged.

The visual observations of specific head movements during X-ray trials as compared with a more generalized pattern of head movements during baseline and control trials are simular to observations made by other investigators. Hendricks (10), using the conditioned suppression technique for critical flicker frequency thresholds determinations, observed that pigeons suppressed key pecking and turned away from the response key when the key light was intermittent. Shumake (11) confirmed this observation in the rhesus monkey. Thus, the change in head movements during X-ray trials observed during the present experiment are probably part of a generalized emotional behavior pattern to the presentation of a discriminative stimulus which is terminated by an unavoidable shock. The possibility exists, however, that the monkey reacts immediately to the onset of the X-ray beam with specific head movements, independent of the conditioned suppression technique.

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